Northern-Hemisphere extra-tropical cyclone activity in 1961-1990: Comparison of the CGCM3 with the NCEP/NCAR reanalyses

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Extra-tropical cyclonic circulation systems induce substantial transport of water vapour, heat and momentum, thus contributing to the maintenance of the time-averaged general circulation of the atmosphere. General circulation models (GCMs) are useful tools for studying a wide range of interacting physical processes that characterize the climate system. Comparison of model simulations with observations provides insights that can aid interpretation of climate variability and future climate-change projections.

The goal of this study is to assess the degree to which the third generation of the Canadian Coupled (atmosphere-ocean) General Circulation Model (CGCM3) replicates extra-tropical cyclone behaviour in the recent climate. An analysis approach was used to identify and track extra-tropical cyclones, and then to compare their statistics over a 30-year period. The statistical method used here includes the computation and mapping of climatological seasonal or monthly means and their standard deviations for various measures of cyclonic activity.

The use of cyclone system climatology for validation is based on the automated objective synoptic systems identification and tracking algorithm of Sinclair (1994, 1997), who was adapted at UQÀM by Rosu (2005). Cyclones are here identified as local maxima of gradient-wind vorticity (ζ_{gr}) computed as the Laplacian of the gridded 1000-hPa geopotential. The use of vorticity captures preliminary stages of large-scale cyclones that would not be detected as pressure minima. Only centres poleward of 20° latitude are included because the gradient wind approximation is not valid close to the equator.

The tracking procedure follows the scheme of Murray and Simmonds (1991a). Tracking attempts to mach cyclones at a time with centres at the next analysis time, 6 h later. The chosen combination of matches is one that minimizes a weighted sum of absolute departures of location, pressure, and vorticity from extrapolated values. In order to locate cyclone centres accurately between grid points, a bicubic spline interpolation has been employed. A Cressman filter (see Sinclair, 1997) was applied several times through the algorithm.

The CGCM3 uses the same ocean component as the earlier version, but a new updated atmospheric component, AGCM3. It is a spectral model with triangular truncation at wave number 47 and 32 levels in the vertical on hybrid coordinates. For this study, model data were first interpolated to pressure levels on a 2.5° lat × 2.5° long grid. The 1000-hPa geopotential was calculated from the model's orography, surface pressure and temperature fields.

The observation-based data used for the comparison/validation are the National Centers for Environmental Prediction and National Center for Atmospheric Research (NCEP/NCAR) reanalyses. The 1000-hPa geopotential from the NCEP/NCAR reanalyses was available on a 2.5° × 2.5° latitude-longitude grid. Model and reanalysis data covering the period 1960 to 1990, four times per day, were then interpolated on a northern hemispheric polar-stereographic grid (97 × 97 points) with a spacing of 180 km at 60° lat.

The algorithm provides information about each cyclone track for a selected period (month, season): date/time, number of centres, their location, and the corresponding ζ_{gr}, cyclonic circulation, and associated precipitable water vapour who is introduced in the algorithm during this study.

In order to eliminate weak perturbations and quasi stationary centres from the cyclone statistics, we imposed following conditions: 1) threshold of ζ_{gr} is $2.5 \cdot 10^{-5}$ s^{-1}, 2) minimum track lifetime is one day, 3) total track length is at least of 1200 km, and 4) minimal distance between final and initial track positions is at least of 600 km.

The measure of cyclone distribution presented here is track density, defined as the number of discrete cyclone tracks passing within 333 km of any grid point. It is obtained by counting the centres just once per track per grid point. This requires cyclones positions to be related into tracks. Because of the overlapping area(s) between neighbouring search circles, one cyclone track may be taken into account at several grid points at the same time.

Fig. 1 shows the NH geographical distribution of the climatological mean of cyclone track density from November to April (NDJFMA). The NCEP/NCAR reanalyses (Fig. 1a) reveal two regions of pronounced maxima. The first extends from Japan toward the Gulf of Alaska, while the second extends from the Great Lakes and North American East Coast, across the North Atlantic and into Sub-Arctic Ocean. Secondary maxima occur over the northern Eurasia and the Gulf of Genoa. Comparison with the results from the CGCM3 (Fig. 1b) confirms this general picture of cyclonic activity, but with a slight under-estimation in the polar region and a larger over-estimation in the oceanic regions of maxima (see Fig. 1c).

Fig. 2 shows the NH geographical distribution of the standard deviation of seasonal-mean cyclone track density for the same period. Results from CGCM3 (Fig. 2b) show a great similarity to those of NCEP/NCAR reanalyses (Fig. 2a). The greatest interannual variability of the track density around the seasonal-mean climatological average occurs in the preferred cyclone regions such as Iceland, the Gulf of Genoa and the East China Sea. The main differences between two distributions of variability (Fig. 2c) occur in the same regions as those seen in the means.

Therefore, in comparison with the NCEP/NCAR reanalyses, the CGCM3 simulations reproduce well the statistics of extra-tropical mobile cyclones, with slightly larger averages of winter season track density (Table 1) and their variability.

NCEP/NCAR	CGCM3
24 183	24 260

Table 1. Total number of cyclone tracks over the 30 extended winter seasons (NDJFMA, 1960/61 to 1989/90).

References

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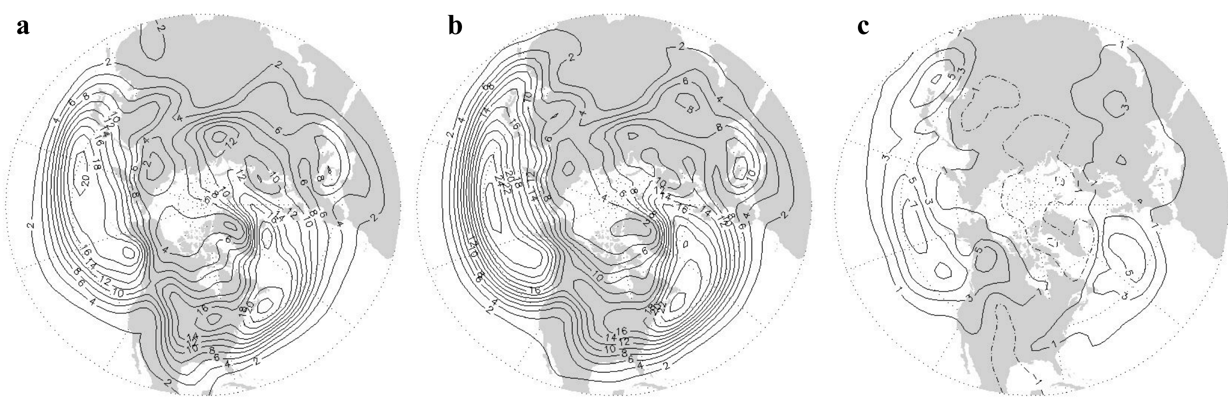

Fig. 1. **Mean of extended winter season (NDJFMA) cyclone track density for the NH.** Contour interval every 2 centres per 333 km circle per season. (a) NCEP/NCAR, (b) CGCM3 and (c) Difference CGCM3 minus NCEP/NCAR (solid lines for positive differences and dashed lines for negative differences).

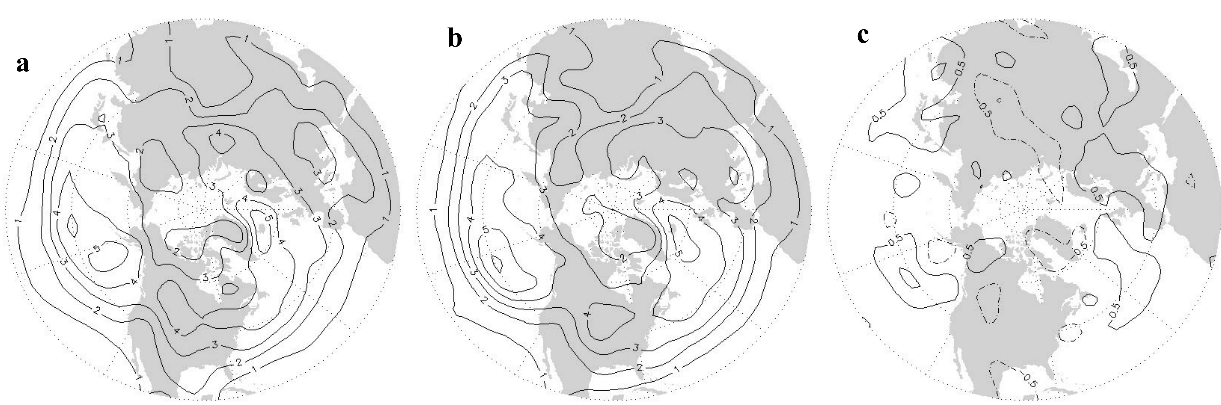

Fig. 2. **As above, but for the standard deviation of seasonal mean cyclone track density.** Contour interval every 1 centre per 333 km circle per season for (a), (b) and (c).